Gamma Shadow Effects on Geomagnetic EMP Rise Time and Amplitude

JOWOG-43 EMP and Fire Special Topic Meeting

DTRA/TASC, Lorton, VA
August 13 – 15, 2013

Hans Kruger

**Lawrence Livermore National Laboratory**

Outline

- MACSYNC 3D geomagnetic EMP code

- Obstructed LOS scenarios investigated:
  - Massive component near warhead
    (not discussed here)
  - Tall buildings surrounding warhead in town square

- Conclusions and observations

3D geomagnetic EMP code MACSYNC forms the composite EMP by superposition of synchrotron radiation mini-pulses

Gamma source
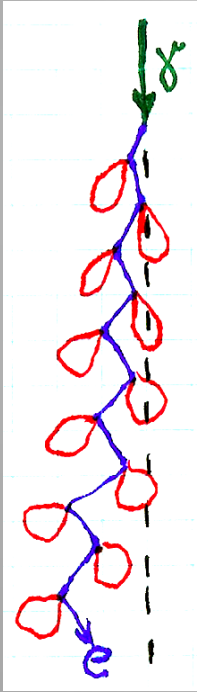
Synch. radiation beacons

- Gamma-electron Monte Carlo transport using LANL's MCNP code coupled to a synchrotron radiation emission/attenuation subroutine

- Synchrotron radiation mini-pulse emitted for every Compton electron transport substep based on instantaneous electron velocity vector and energy

- Each synch rad mini-pulse attenuated along LOS between instantaneous electron position and observer

- Attenuation based on pre-loaded air conductivity subroutine specific to each gamma energy or spectrum

- Subroutine computes air conductivity as a function of instantaneous distance r from burst point and time elapsed since first gamma arrival at r

- Conductivity is corrected for conduction electron attachment during interval between initial creation of air ionization and arrival of synch rad mini-pulse

- Mini-pulses tallied in arrival-time-at-observer bins

- Vector addition of mini-pulses in each bin => composite EMP at observer

MACSYNC geometry for a detonation in a town square surrounded by tall buildings
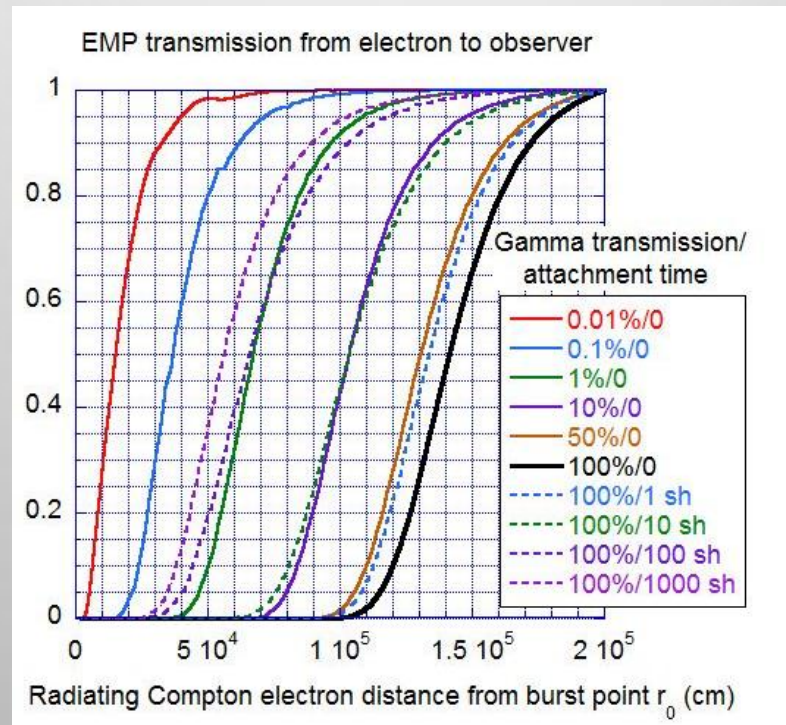
Building block ("wall"): 100 m deep; 15, 36.4, or 99 m high
Circular town "square" radius = 100m
Variable gamma transmission of "wall"
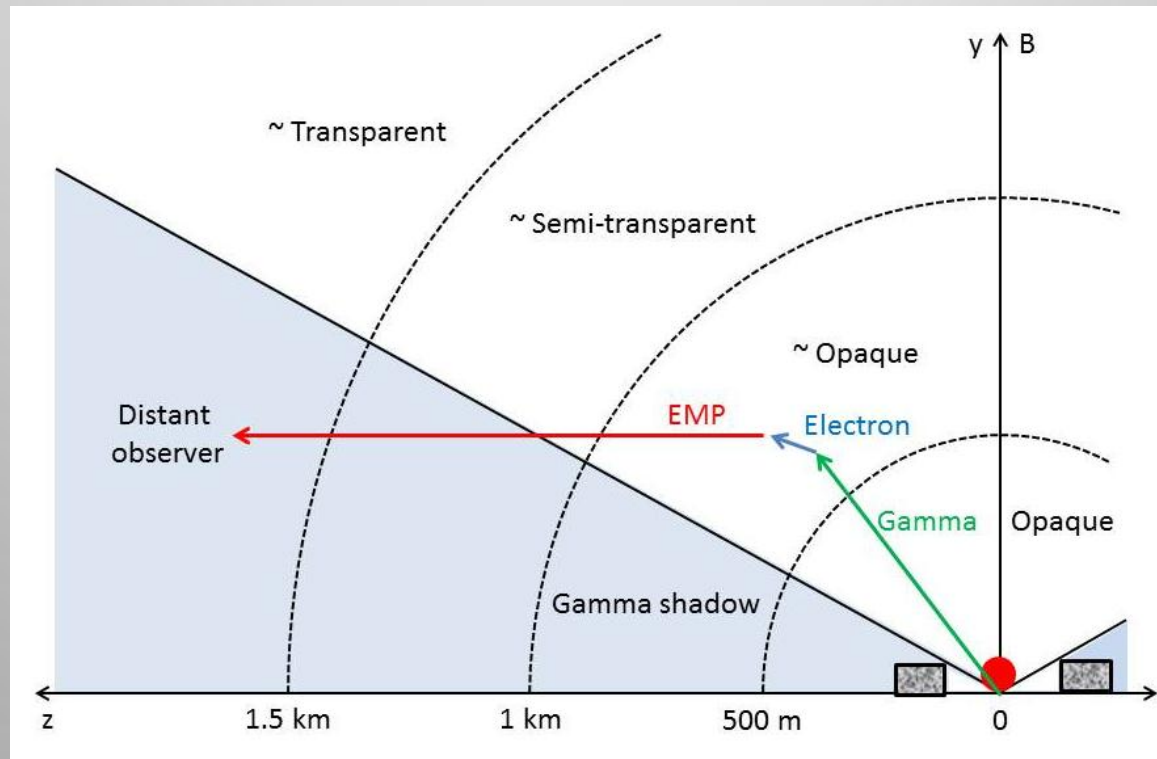
# Gamma attenuation in the shadow cone reduces the EMP-opaque volume

1 kt total yield - 0.3% 3 Mev gammas – 0.01 sh step output pulse

At later times, conduction electron attachment also reduces the opaque volume
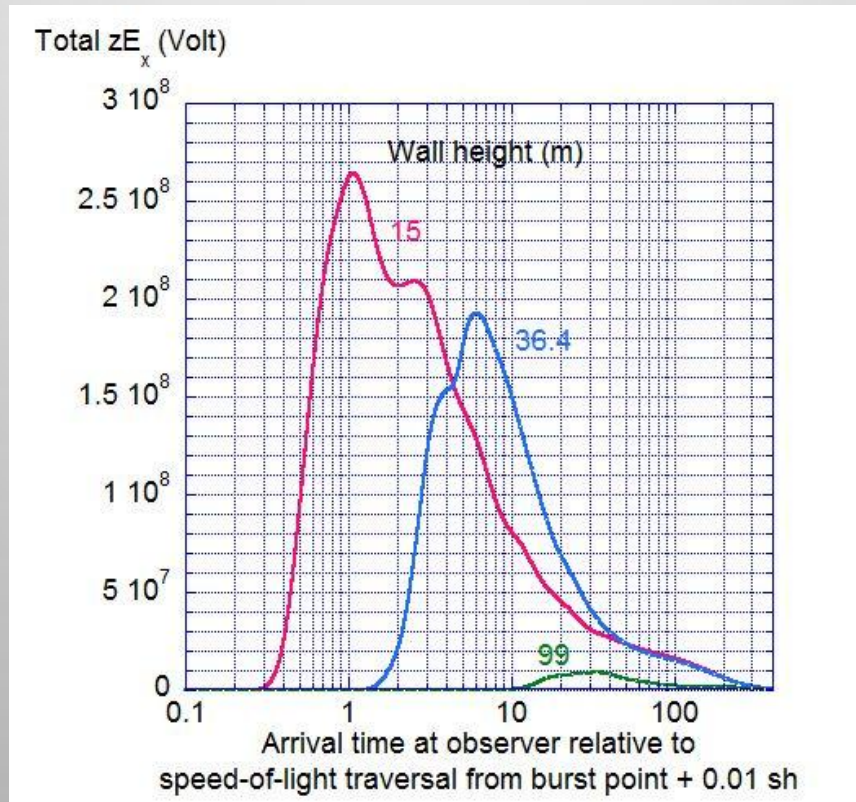
Reduced ionization and conductivity in gamma shadow greatly increases EMP amplitude

1 kT total yield - 0.3% 3 Mev gammas - 0.01 sh step output pulse - B=0.5 gauss
36.4 m wall height
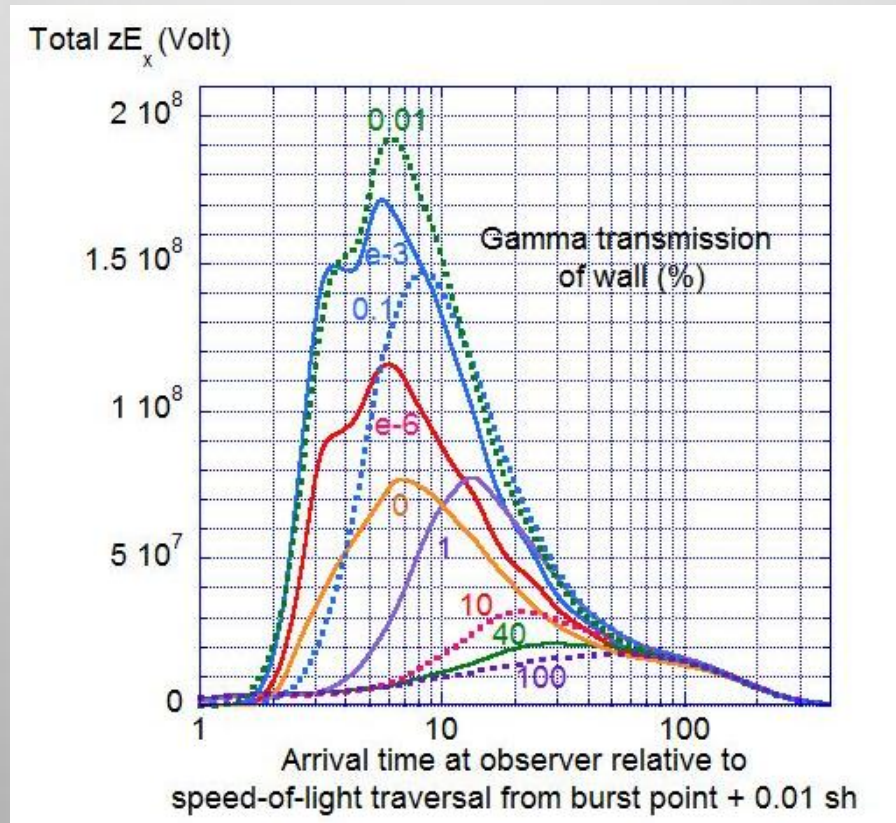
Gamma shadow cone angle dominates
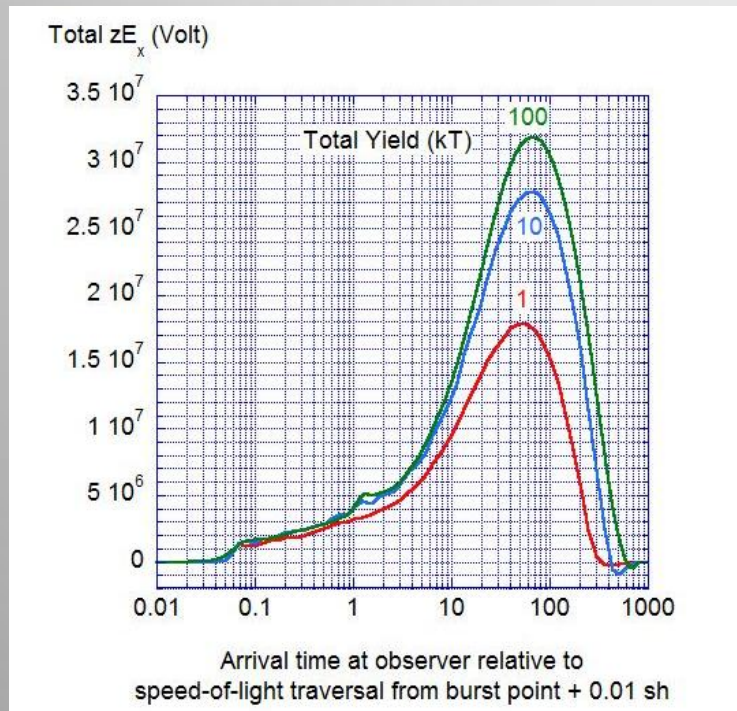# EMP amplitude and rise time

1 kT total yield - 100 m radius from burst point to wall - 0.01% gamma transmission
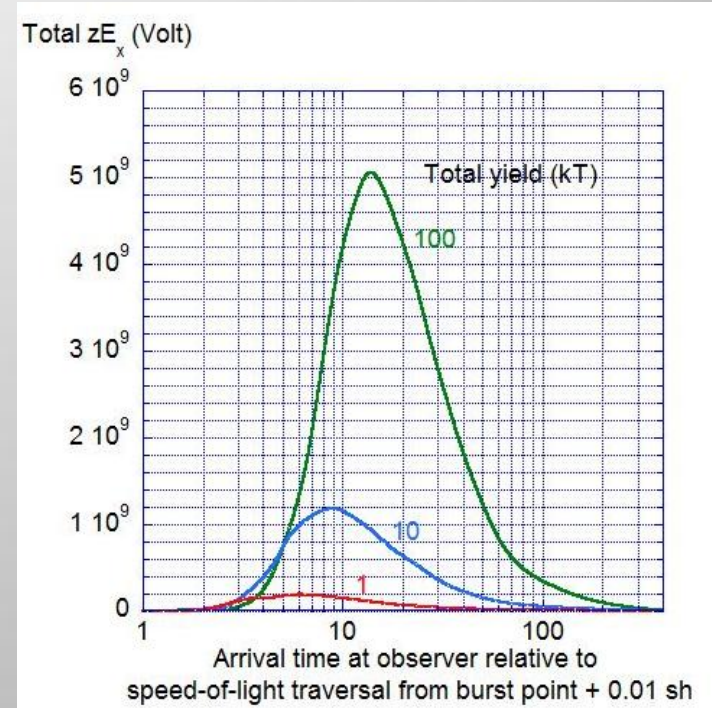
EMP amplitude increase with yield does not saturate without a significant air conductivity in gamma shadow

36.4 m wall height - 100 m radius from burst point to wall

No gamma shadow
(100% gamma transmission)

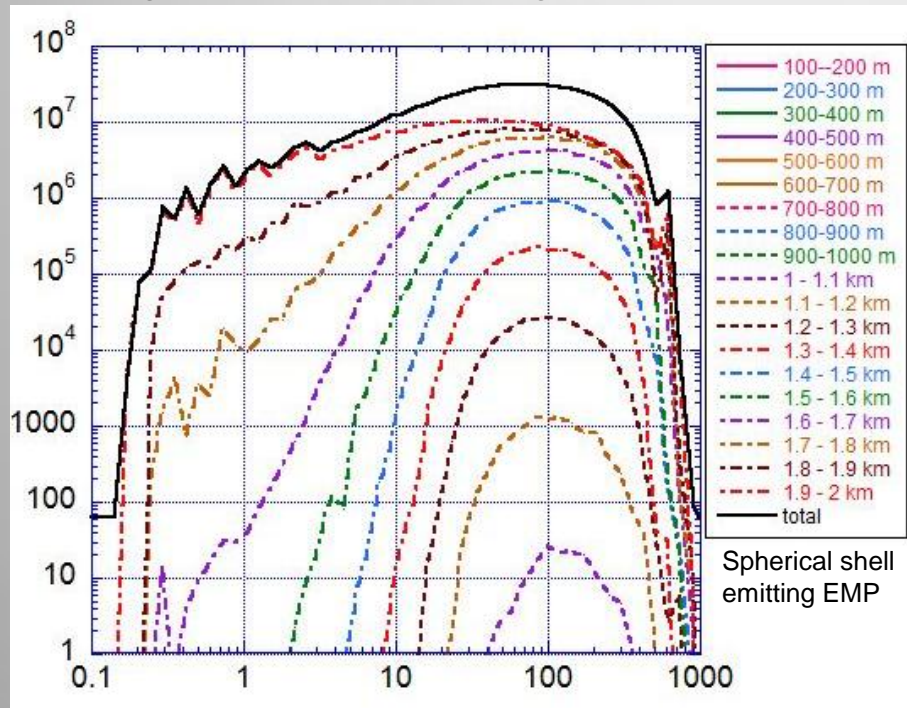With gamma shadow
(0.01% gamma transmission)

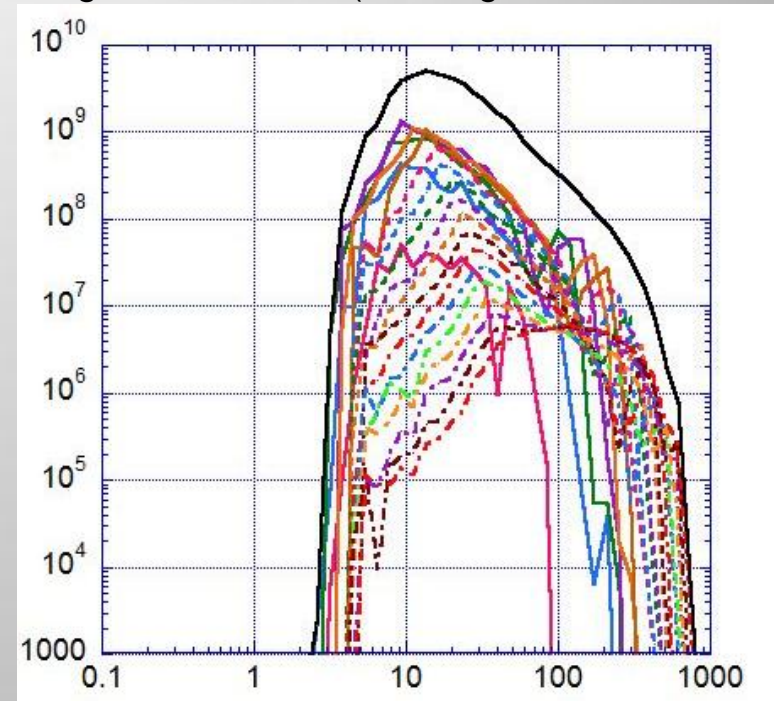However – expect amplitude limited by air breakdown

EM leakage channel in gamma shadow is transparent closer to the source

100 kT - 36.4 m wall height - 100 m radius from burst point to wall

No gamma shadow (100% gamma transmission)

With gamma shadow (0.01% gamma transmission)

Legend:
- 100--200 m
- 200-300 m
- 300-400 m
- 400-500 m
- 500-600 m
- 600-700 m
- 700-800 m
- 800-900 m
- 900-1000 m
- 1 - 1.1 km
- 1.1 - 1.2 km
- 1.2 - 1.3 km
- 1.3 - 1.4 km
- 1.4 - 1.5 km
- 1.5 - 1.6 km
- 1.6 - 1.7 km
- 1.7 - 1.8 km
- 1.8 - 1.9 km
- 1.9 - 2 km
- total

Spherical shell emitting EMP

Arrival time at observer relative to speed-of-light traversal from burst point + 0.01 sh

In absence of gamma shadow, volume within ~ 1.5 km radius is initially opaque, more transparent later after conductivity reduction from electron attachment

Computed fields approach air breakdown threshold

Threshold at sea level: ~3 MV/m static, ~ 5 MV/m a few ns into pulse
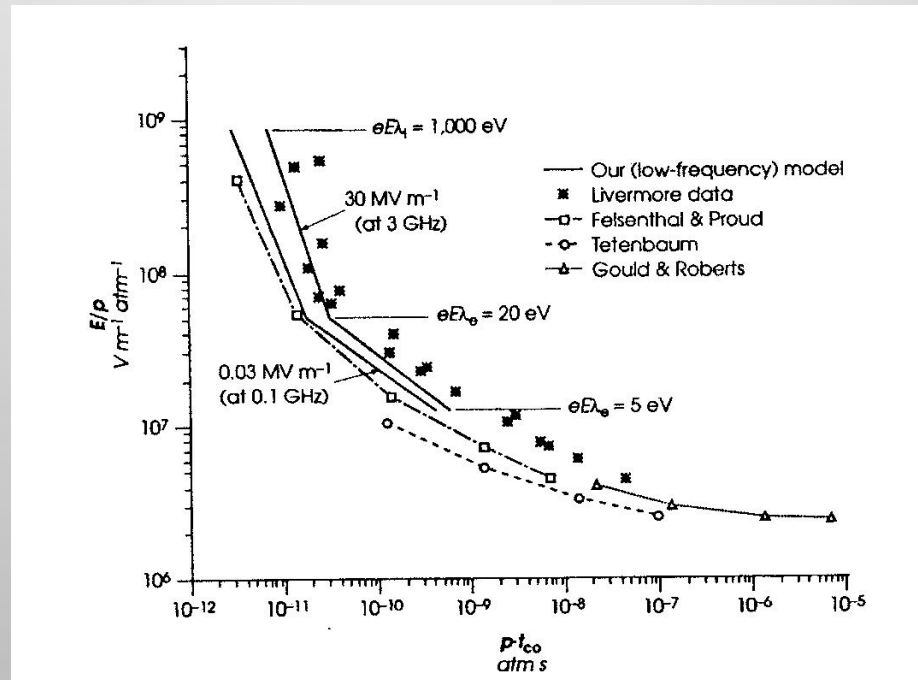
Ref.: Fenstermacher and vanHippel,, Science & Global Security, 1991, Vol. 2, pp. 301 - 324

Breakdown threshold at higher altitudes is less (proportional to air density)
and field likely to be significantly limited by air breakdown

Conclusions and observations

- Dense LOS obstruction produces a gamma shadow with greatly reduced air ionization and conductivity.
- Creates EMP leakage channel through highly attenuating volume around burst point:
  - greatly increased EMP amplitude,
  - little amplitude saturation with increasing yield,
  - probably not limited by air breakdown.
- Resulting off-LOS paths for first-arriving EM radiation greatly increase EMP rise time, masking rise time of fast gamma pulses.
- Expect similar effects of LOS obstruction on amplitude and rise time for:
  - geomagnetic EMP from high-altitude bursts,
  - ground asymmetry EMP in urban settings.
- Because of potential impact on hardening standards and various National applications of EMP, independent verification advisable with more conventional 3D Maxwell's equations solver (yet to be developed) and laboratory experiments.